Sustainable progression of technology education for atomic energy engineering in tsuyama national college of technology

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Abstract
This study describes the achievements of a program that provides technology education about radiation to develop practical core engineers, then the effects of the programed were discussed. An education program starting at an early age and continuous and consistent educational agendas through seven years of college has been constructed in collaboration with regional organizations. Subjects relating to atomic energy or nuclear engineering were regrouped as “Subjects Related to Atomic Power Education” for most grades in each department. These subjects were included in the syllabus and the student guide book to emphasize a continuous and consistent policy throughout the seven-year period of college study, comprising the five-year system and the additional two-year advanced course. Furthermore, the content of lectures, experiments, and internships was enriched and realigned in collaboration with the Japan Atomic Energy Agency (JAEA), Okayama University, and Chugoku Electric Power Co., Inc. Additional educational materials were developed from inspection visits by teaching staff to atomic energy facilities were also used in the classes. Two student experiment textbooks were developed to promote two of the subjects related to atomic energy: “Cloud Chamber Experiment” and “A Test of γ-ray Inverse Square Law.” In addition to the expansion and rearrangement of atomic power education, research on atomic power conducted for graduation thesis projects was undertaken to enhance educational and research activities. Some examples are as follows: “Study on the Relation between γ Dose Rate and Rainfall in Northern Okayama Area,” “Remote Sensing of Radiation Dose Rate by Customizing an Autonomous Robot,” and “Nuclear Reaction Analysis for Composition Measurement of BN Thin Films.” It should be noted that an atomic-energy-related education working group has been in place officially to continue the above activities in the college since 2011. In consequence, although government subsidy has been decreasing, both human and material resources have been enhanced, and many students with a satisfactory understanding of atomic energy are being developed.

Key words: Technology education, Atomic energy, National college of technology, Dose rate, Graduation thesis, Education aided system, Problem based learning, Applied physics experiment, Second world
1. Introduction

The reduction target for greenhouse gas emissions in 2010, which Japan promised to the world in December 1997 in the “Kyoto Protocol to the United Nations Framework Convention on Climate Change,” was 6% based on FY1990 (Ministry of Economy, 2008). With regard to environmental and new energy research in Japan, the “Cool Earth-Innovative Energy Technology Program” (Ministry of Economy, 2008) was agreed upon by the Ministry of Economy, Trade and Technology in Japan in 2008. In the program, 21 technologies that could potentially contribute significantly to CO₂ emission reductions were selected as technologies with which our country could lead the world in fields such as power generation/transmission, transport, industry, and in the commercial/residential sectors to accelerate innovative technological development in the energy field. Advanced nuclear power generation is one of these technologies.

In addition, it should be noted that there is a specific energy-supplying structure in the Chugoku area (Kato, et al., 2012) in which coal-combustion thermal-power generation and atomic power generation produce 35% and 8% of the electric power supply as compared to the overall average of 20% and 18% for Japan, respectively. To reduce CO₂ emissions, it is necessary to improve the efficiency of coal-combustion thermal-power generation, introduce renewal energy and/or atomic energy power generation.

Furthermore, the mined soil for obtaining uranium ore has been a controversial issue in the Tsuyama region; therefore, each graduate should have full quantitative knowledge on radiation and the effects of radiation as well as their fundamental engineering knowledge to have an informed opinion as an engineer and to be able to advise the public appropriately.

Therefore, the following educational programs in atomic energy have been developed at Tsuyama National College of Technology (Tsuyama NCT) for core engineers in 2008, in collaboration with the JAEA, Okayama University, and the Chugoku Electric Power Co., Inc. (Kato, et al., 2012).

(1) An early-age introductory education program and a continuous agenda of atomic energy education throughout the college, (2) development and reorganization of the content of lectures, experiments, and internships, and (3) enhancement of research works for graduation theses on atomic energy: specifically, remote control and mechatronics technologies, material technologies for use as radiation, decommissioning technologies for the reuse of waste.

Since 2009, the programs have been expanded and evolved by (a) the reinforcement of education, (b) the upgrade of education and forming of an education-aided system, and (c) the upgrade and establishing of research, so that programs can continue even if any external subsidy supporting the programs is withdrawn. In this study, these educational trials and their effects are discussed.

2. Result and discussion

2.1 Trials for strengthening the educational organization and the effects

In this section, the trial to strengthen the educational organization and their effects are discussed.

2.1.1 Establishing “Subjects Related to Atomic Power Education” and an official working group

Subjects relating to atomic energy or nuclear engineering were regrouped as “Subjects Related to Atomic Power Education” for most grades in each department. These subjects have been included in the syllabus and the student guide book to emphasize a continuous and consistent policy throughout the seven-year period of college study, comprising the five-year system and the additional two-year advanced course (Kato, et al., 2012). In the past, there had been no organization in the college; therefore, teaching members working for the subsidized project were temporarily organized in 2008, and organizational activities were undertaken. However, external subsidies were not always available; hence, it was decided that a working group for the atomic-energy-related activities would be officially established in the college in FY2011 by a petition to the higher committee of the college, and the annual budget for this has already been approved. As a result, the activities related to atomic energy education were authorized as official school affairs, and the program management process is now in place. The number of subjects related to atomic energy technology in the five-year associate’s degree course has reached much more than planned as shown in Fig.1. The number of students registered in these subjects has also exceeded the planned.

The reason for this great success should be discussed more. In the original plan, a few subjects such as nuclear engineering and safety engineering were expected to be newly introduced. In the point of the number of educational staffs and the subjects offered, however, two subjects had to be reduced if new two subjects were added due to the small
educational organization consisting of four departments having 40 students in each department, thus adjustment of the possible subjects were difficulties. Namely, initially assumed staffs were reluctant since they needed to give up their conventional subjects. Thus alternative initiatives were discussed, and contents of all syllabuses were investigated. As the result, it was found that nuclear related technologies were partially taught in many subjects, further atomic related technologies can be replaced to some subjects if the number of tuition is a few in a semester. For example, in “System Engineering”, the calculation of reliability and safety in chemical industrial complex will be replaced to that of nuclear plants, in “Environment Science”, lectures on nuclear engineering can be increased, and in “Industry Ethics”, issues on recall of automobile will be changed to the accident at Three Mile Island in United State and criticality accident at a plant of Japan Nuclear Fuel Conversion Co. in Japan. Consequently, twelve academic staffs have given the lectures on nuclear technologies such as nuclear reaction, safety engineering in fourteen subjects, and the initiatives on nuclear engineering were smoothly introduced. As a matter of course, at the initial stage, unsteady works such as lab-tour and inspection to create educational materials for the lectures were carried out as mentioned below. It should be noted that no negative events, oppositions nor prejudges took place as the related academic staffs were twelve among around 60 staffs.

Finally, it has been suggested that the collaboration of the related academic staffs in their specialized fields and sharing of the contents each other were key factors in expanding the number of students enrolled since there are almost no staffs specialized in nuclear technology. Students interested in nuclear technology have been working in nuclear power station after graduation of the associate’s degree course, furthermore student who wanted to have further study entered to the master course in department of nuclear system safety engineering in Nagaoka University of Technology.

![Fig.1 Progress in the number of subjects and students registered to the subjects related to atomic energy](image)

**2.1.2 Participation in the Institute of National Colleges of Technology project**

A project “The Training of Practical Engineering through Cooperation among Institutions in the Nuclear power field laying emphasis on Education in Safety and in Disaster prevention” started in FY2011. The feasibility study was conducted at the end of FY2010 before the Great East Japan Earthquake on March 11th, 2011. In the project, 33 National Colleges of Technology in Japan joined with Nagaoka University of Technology, the Radiation Application Development Association, and the JAEA to provide lectures and experiments, as well as practice in safety and in disaster prevention, in the field of nuclear power engineering.

Some Tsuyama NCT students spontaneously participated in the one-week seminar held in the JAEA Tokai Research and Development Center and the debriefing session of the graduation thesis held in Tokyo, although these events were held during the spring holiday and did not contribute toward the unit. A high level of interest in nuclear technology was thus recognized. The former event was held just before the Great East Japan Earthquake, and two students returning from the JAEA were trapped in the train and spent the night seeking shelter in a nearby gymnasium. It also became an opportunity for thinking about the importance of safety and disaster prevention. Significantly affected by the trend of public opinion after the Great East Japan Earthquake, graduates with expert knowledge on radiation and informed opinion as engineers, and who are able to advise the public appropriately, could be developed.

As part of the project, the structure in which a key university and institution lead in providing practical education in radiation and safety has been designed, further organized, and achievement has been measured, for example, data were collected across the country (Institute of National College of Technology Japan, 2012).
Thanks to these organizational strategy and construction of network, external competitive funds have been obtained in these two years by the official working group. It has been suggested that organization and its continuous activities help sustainable development of atomic energy education.

2.2 Upgrade of the lecture, experiment, and internship and the effects
In this section, the efforts to upgrade to intensify the lecture, experiment, and internship in the associate’s degree courses and in the advanced course and the effects are discussed.

2.2.1 Lecture by a foreign researcher
A foreign researcher, Professor P. Heino from Tampere University of Applied Sciences in Finland, was invited by Okayama University to give a special lecture on advanced engineering titled “Decision making industrial risk management,” focusing on safety and security engineering. Students in the advanced course wrote reports on the lecture, confirming that many of them realized the importance of safety and sustainability of energy, including atomic energy. About 30 students in the advanced course attended the lecture, with commentary by Professor Suzuki from Okayama University. There was a lively question-and-answer session in English after the lecture, and the confidence of the students impressed both professors. Active questions were also observed at the lecture by a foreign professor last time, thus it is suggested that lecture by foreign researcher activates the class or the motivation of students probably because of the worldwide topics and/or the extraordinary atmosphere.

2.2.2 Upgrade of teaching staff and educational materials
To enhance nuclear education in Tsuyama NCT, some teaching staff were sent to a prototype sodium-cooled fast reactor, Rokkasho-mura, where multiple facilities exist for reprocessing, the site of a new nuclear power plant, Kaminoseki Chugoku Electric (Fig.4), and the National Institute for Fusion Science. The lectures “Environment and recycling,” “Systems engineering,” “Energy engineering,” and “Engineering of electrical energy” were updated on the basis of the knowledge obtained. This type of inspection should be conducted in other organizations, since it is very effective for quickly ramping up the capability of educational staff (Kure National College of Technology, 2010), (Nagaoka University of Technology, 2010)

Furthermore, the knowledge and information obtained were documented using Microsoft PowerPoint and Word for use as educational materials as shown in Fig.2 and Fig.3. These materials have since been utilized in various atomic energy-related subjects, and academic staffs have felt that these materials is persuasive.

Fig.2 Questions for homework and report on nuclear power plant prepared after the inspection of fast breeder reactor.

Questions for homework and report
Q1: Explain using the following terms, what's going on in a chain fission reactor.
   [Moderator, Thermal neutron, Fast neutron, Uranium-235]

Q2: Explain the difference in how the generation of pressurized water reactors and boiling water reactors using the following terms
   [Steam generator, Turbine, Steam]

Q3: Do you think that it needs nuclear power for Japan, or do you think unnecessary? Also, explain why you think so.
   (Be explained by at least 1000 or more characters)
2.2.3 Development of an education-aided system

The purposes of this system are to help the teaching staff (Kobayashi, et al., 2011a) visualize the content of the subjects and their educational materials and to promote the following two points: (a) share knowledge of information and teaching materials to streamline and to sophisticate the education; (b) anyone can give a lecture by selecting required educational materials using a system where the menu is presented as a wizard, rather than simply a repository of documents, in addition to improving operational efficiency.

Fig.4 shows the entry page. By clicking the action button of the desired item, we can move forward to the necessary links. For example, if you go to the page on the nuclear-human-resource-development-related subjects in Fig.5, you can access the page on the educational materials and/or the syllabus for each subject, as shown in Fig.6. Also, if you go to the menu of nuclear-related materials in Fig.7, selection of materials that meet the education level and the item from the original and off-the-shelf materials is enabled.

Fig.4 Entry page of the education aide system where menu is presented as wizard.
2.2.4 Debate with the engineers of Chugoku Electric Power

Twenty-nine students enrolled in the fifth grade, who registered for the subjects of “Energy Engineering” and “Environment and Recycling,” toured the Chugoku Electric Shimane Nuclear Power Station and further carried out exchanges with field engineers, attempting “interactive education,” as shown in Fig. 8. As a result of this new method,
the students could join the debate much more eagerly than in a conventional site tour, and most of the students were satisfied according to the questionnaire. This tour has been very popular for students therefore it has been conducted every year. The typical theme of debate is on “agree or disagree with nuclear power”. Knowledge of renewable energy and conventional thermal power generation are required as well as nuclear power. The engineers could give some comments on the debate. In question time to the field engineers, Frequently Asked Questions were the reason for application to the electric power company or nuclear power station, the job satisfaction in the nuclear power station and the social responsibility. Suggestive and candid opinions were replied to the students by the engineers. This could be a good example of “interactive education” or “active learning” recently recommended in education fields.

![Fig.8 Debate with the field engineers of Chugoku Electric Power for trying “interactive education”.

2.2.5 Enhancement of education in a subject

In a subject of experiment in applied physics, natural radiation dose rate was observed using cloud chamber to make students understand the existence of radiation in their surroundings, further the reducing methods of radiation dose with metal shield or by making distance away from radioactive were understood. Especially, students came to realize that the dose rate decreases by Inverse Square Law in the distance (Fig.9). A lecture was given by Prof. Ichikawa from Okayama University. Every year, event related to atomic energy corroborated with JAEA and Okayama Univ. has been held in Okayama prefecture thus the students of Tsuyama NCT have joined. In 2011, a symposium, where the status of the investigation of the accident of Fukushima Nuclear Power Station was reviewed by Prof. Ichikawa, was held in Tsuyama NCT, the students and education staffs as well as director of Tsuyama NCT joined the symposium. In the symposium importance of scientific knowledge and information to understand how engineers should act in the situation was impressed.

![Fig.9 Implementation of the class in applied physics experiment.

2.3 Enhancement of research works

2.3.1 Graduation theses

Research works for the graduation thesis in the associate’s degree course were conducted. The reason for selecting the theme, the devised point and the educational effects and so on are discussed.
In FY2010, the papers “Study on the Relation between Dose Rate and Rainfall in Northern Okayama Area”, “Production of a Text on the Radiation Measurement in Applied Physics Experiment for the Fourth-grade Students” (“Cloud Chamber Experiment” and “A Test of γ ray Inverse Square Law”) and “Nuclear Reaction Analysis for Composition Measurement of BN thin films” (Kobayashi, et al., 2011b) were conducted. In “Study on the Relation between Dose Rate and Rainfall in Northern Okayama Area,” in order to make students understand the existence of natural radiation and the part of radiation come from underground, surrounding materials related to rainfall was selected. The undergraduate student showed interest very much in the phenomena where dose rate increased after rain fall due to the fall of radon in the sky (Moritani and Kato, 2010). In “Production of a Text on the Radiation Measurement in Applied Physics Experiment for the Fourth-grade Students”, textbook for the experiment used for class was prepared by an undergraduate student for a trial to make student create educational material autonomously. The equations and graphs were selected by the undergraduate student, and degree of difficulty and time taken were examined. The textbook has been used in a subject of experiment in applied physics, thus the verification has almost finished. It was found that this trial was useful for the student to learn atomic energy technology, and the textbook is very suitable for students as well. In “Nuclear Reaction Analysis for Composition Measurement of BN thin films”, it was taught that nuclear reaction is used effectively in a field of chemical analysis. The student presented his thesis at an international conference.

In fiscal year 2011, in addition to the progression of the above research studies, further research work, “Research on Radiation Measurement using an Autonomous Driving Vehicle” (Morisato, et al., 2011), (Kobayashi, et al., 2011c) was conducted to make students to have interest in atomic energy (Fig.10). Using the autonomous driving vehicle, it was confirmed that dose rate map can be formed easily without measuring by hand. This theme started before the Fukushima accident, the continued work has still most popular theme in the author’s laboratory since both robotics and nuclear related technologies were learned. A student conducted his graduation research on a material for delivery class in junior high school in order to teach radiation using a small cloud chamber. The student visited a junior high school accompanied by his supervisor, then he gave a lecture for younger students in the class by himself. The results including questioner were presented in a symposium organized by Institute of National College of Technology Japan. The student recognized the importance to give correct information to junior high school students who concerns and are worried about nuclear issue without any scientific knowledge. This trial is also an example of “active learning”.

It has been suggested that it is possible to give nuclear power education by combined to other field to make students have interest in atomic energy, although the author’s college does not have nuclear engineering course.

3.3.2 Research on education

A project for learning nuclear energy safety was carried out through e-learning (Kanematsu, et al., 2012). The virtual classroom was built on a virtual island of Second Life owned by Nagaoka University of Technology. A teacher gave the students a short lecture and proposed the problem as shown in Fig.11. The advantage of virtual classroom over e-learning, which is generally asynchronous and one-to-one in communication, is synchronous and many-to-many, namely group

Fig.10 Example of the radiation measurement using autonomous driving vehicle
work is possible. The advantage over actual classroom is distance learning. The system is cheaper than TV meeting system. Students understood the contents very well and solved the problem through discussion in Metaverse. The results indicated very clearly that this kind of Problem Based Learning (PBL) class was obviously suitable for actual e-learning in nuclear engineering.

![Image](image_url)

Fig.11 Trial for PBL using the virtual classroom built on a virtual island of Second Life owned by Nagaoka University of Technology.

4. Conclusion

Technology education for atomic energy engineering to cultivate practical core engineers was conducted in collaboration with related universities, organizations and companies, and the effects were discussed. The following results were obtained.

1. An education program starting at an early age and continuous and consistent educational agendas through seven years of college were reinforced by officially establishing an initial working group in the college to promote the sustainable education of atomic energy science and engineering, even without an external subsidy.

2. To level up the quality of “Subjects Related to Atomic Power Education” included in the syllabus and the student guide book, an education-aided system was developed, in which information and knowledge obtained from the teaching staff’s technical inspections were documented using Power Point and were given to teaching staff with appropriate educational materials.

3. Research studies for graduation theses in associate’s degree courses and in advanced courses were started to make students to have interest in atomic energy and to promote sustainable development in its education.

4. In conclusion, a total of 14 subject areas, more than 800 registered students, and 12 members of the teaching staff related to atomic energy technology have been estimated so far.

5. It is suggested that the key words of effective educational methods are “collaboration of the related academic staffs”, “organizational strategy and construction of network”, “share knowledge of information and teaching materials”, ” “worldwide topics and/or extraordinary atmosphere”, “interactive education”, “active learning”, “make student create educational material autonomously” and “give nuclear power education by combined to other field”.

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